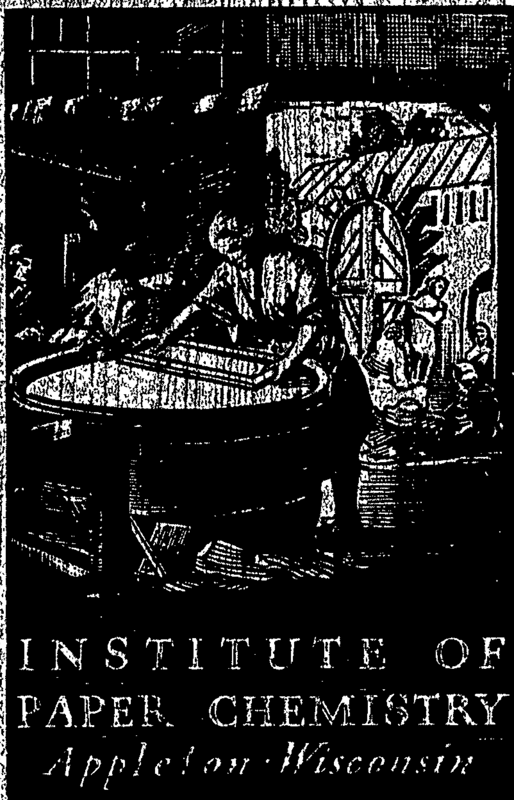

GENETIC IMPROVEMENT OF LARCH

Project 3409

Report Five

A Progress Report

to

MEMBERS OF GROUP PROJECT 3409

February 15, 1985

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

GENETIC IMPROVEMENT OF LARCH

SUMMARY

July 1, 1984 marked the start of the sixth year of the larch improvement program. Progress has been good this past year and 1985/86 promises to be another outstanding year. Parent tree selections now total 135. Because a limited number of appropriate larch stands remain for use as sources of additional parent tree selections, negotiations are now underway to bring in additional parent tree selections from Europe and Canada. Plans are also being made to initiate selection work on tamarack (Eastern larch). A total of 849 grafts were made in 1984, and the grafting emphasized previously selected parent trees and the 20 clones slated for use in the project's first European larch seed orchards.

Seed purchases resulted in our obtaining 23 additional sources of larch and the recollection of one source that has shown promise in early field plantings. Most acquisitions were of just 1-2 pounds; however, there were several instances in which larger amounts were purchased, amounts suitable for use in operational plantings. The sources we feel are most suitable for the Lake States and Northeast, based upon limited and scattered provenance trial data, are Sudeten sources from southern Poland and northern Czechoslovakia, sources from the Tatra region in northern Czechoslovakia, and sources from central Czechoslovakia and central Poland.

Needle cast disease, because of its potential to decrease tree growth and in some situations cause mortality, is being monitored closely. This fungus disease causes defoliation of larch and appears to be most serious in the Lake

States on French and high elevation Austrian sources. Resistance to needle cast appears to be greatest in sources from the northern part of the range in Europe and in Japanese and hybrid larch. A cooperative program is being worked out with the U.S. Forest Service, North Central Forest Experiment Station to screen a number of additional sources. Western larch has also been shown to be susceptible to the disease.

Visits to three organizations in Europe with experience in establishment and management of larch seed orchards resulted in the development of a list of recommended procedures. These recommendations included the use of grafted clonal orchards with a minimum of 20 clones per orchard, and the use of wide spacings (30 x 30 feet) and techniques to speed early growth. Also recommended was the use of locations as far south as possible, taking advantage of lake and/or ocean effects when possible, and the location of orchards on well-drained, medium-textured upland sites. Specific recommendations were also obtained for hybrid seed orchard designs.

Plans have been completed for the establishment of our first seed orchards in north central Wisconsin in the spring of 1985. Instead of one complete orchard, two "half-orchards" will be outplanted. The orchards will be composed of 20 clones of European larch of Sudeten, Polish, and Czechoslovakian origins. When completed, the orchards will contain 400 trees (20 clones of 20 ramets/clone) growing at a spacing of 30 x 30 feet. First seed production is expected in 12-14 years.

Replicated field plantings which have been established on a variety of sites on cooperator lands are just starting to give us preliminary results. These plantings were expected to be a learning experience and were established to provide data on early growth and survival and after 15 to 20 years provide an additional source of known-origin parent trees. Both early survival and early growth has been less than anticipated due primarily to poor condition of planting stock, excessive vegetative competition, frost injury to Japanese larch sources, and in some instances, dry growing conditions. Of the five trials planted to date, it appears one will be abandoned because of low survival. The others have test material survival rates of 53 to 99% and are beginning to show differences between materials in growth rate.

During our parent tree selection work we became aware of two Japanese larch provenance trials established by the University of Wisconsin in 1960 and 1961. During the selection process it became apparent that the trials should be measured. One of the plantings was measured this past fall at age 25, and the results provide an interesting story. There were survival differences between the Japanese larch sources but no difference in height or diameter growth rate. The tamarack (Eastern larch) control source had good survival (77%) but was slower in both height and diameter growth. The five selected trees from these plantings are expected to be useful additions to our list of parent tree selections.

Three demonstration plantings were visited and evaluated this past summer and each provided information of considerable value. Consolidated Paper's Winchester planting (planted in 1981) had what appeared to be below acceptable survival and growth, but during the last two growing seasons the planting has improved greatly in performance and overall appearance and now, except for the poorly drained wet areas and an area of heavy aspen suckering, has adequate stocking with most stems 4-6 feet tall and growing rapidly. The Michigan DNR planting near Covington, Michigan continues to demonstrate the capability of Japanese and European larch to recover from an adverse start (poor condition of stock and inexperienced planters). The planting cannot be considered a success, but there are parts of the area where the larch are doing well and the lessons learned will prove to be invaluable. The third demonstration planting visited is a Michigan Tech. herbicide trial. This trial involves eight herbicides applied as site preparation chemicals the fall of 1983. First year survival and growth of larch looks very promising on several of the treatments and confirms the belief by several individuals that there will be appropriate site prep and herbicide release chemicals that can be recommended for use with larch by the fall of 1985.

Project work with herbicides along with observations on the trials established by Bob Sajdak of Michigan Tech. and on studies by several member companies leaves little doubt the herbicide problem will be solved. Although larch is more sensitive to herbicides than pine or spruce, there are techniques, because of larch's rapid early growth, that should allow successful plantings to be established on a routine basis. One of the most promising methods combines mechanical site prep using a Brakke or similar scarifier and a chemical treatment using either Velpar spot treatment between rows or banding with Oust.

Since economic returns are usually the bottom line in forestry, the economic returns from growing European larch at several rotation ages, growth rates, stumpage values, establishment costs, and management costs were investigated. The results suggest economic returns could vary from 3.6 to 8.5%, depending upon growth rate (site quality) and stumpage values. For pulpwood production the best rotation ages appear to be 22 to 25 years. Economic returns were more sensitive to changes in establishment costs than changes in annual management fees. Economic returns for growing larch were compared with estimated returns for growing pine and spruce on Vilas fine sand soils. Using current Wisconsin stumpage values, returns on investments are 1.2 to 1.6% greater for larch than for the pines and 2.4 to 3.1% greater for larch than for white spruce.

Project plans for the coming year include (1) propagation and establishment of European larch seed orchards, (2) importation of foreign cooperator larch selections, (3) cooperation with U.S.F.S. needle cast screening, (4) a chemical site preparation trial to screen for herbicides suitable for larch, (5) beginning tamarack selection, (6) the production of stock for a replicated field trial and a provenance trial, and (7) continued acquisition of known origin larch seed.

INTRODUCTION

Last spring's progress moved the larch program a step closer to one of the program's major goals with the grafting of the first twenty-clone seed orchard. Instead of one eight-acre orchard, this first orchard is being planted out as two half-orchards. The other half of the orchards will be grafted in 1985 and field planted the spring of 1986. Seed production is expected to begin in about 10-12 years. Full production is expected by age 16 to 18 years. Seed production during good years is anticipated to be 8 to 15 pounds per acre. With the present price of $150 to $250 per pound for good quality European larch seed, the economics of larch seed orchards is very encouraging, even with good seed production occurring only every three or four years.

The economics of growing European larch as a source of fiber looks equally promising. Larch, when compared with red pine, had a rate of return that was about 1.5 percent greater. This greater rate of return resulted because of the faster growth rate and higher value assigned to the wood of European larch. The higher wood value was the result of larch's superior pulp yield and pulp properties. In the report that follows, the economics of growing larch is evaluated and compared with the anticipated returns from growing white spruce, red pine, jack pine, and northern hardwoods on Vilas fine sand.

Also described are the most recent wood quality values for evaluating parent trees and information for the growth of the demonstration and the replicated field plantings. Preliminary information is also provided on herbicides that have considerable promise for use in establishing larch plantings.

SELECTION AND PROPAGATION

SELECTION

The availability of suitable larch stands within which to make parent tree selections is becoming limited. Only one selection was made in 1984. There are several widely scattered plantations that have not been visited and may contain suitable selections. It is intended that these plantings be observed, but it appears that it is now appropriate to seek selections through the exchange of materials with other programs, primarily those in Canada. Restrictions on the importation of Larix materials into the United States from Europe and Asia make it more difficult to arrange an exchange with foreign cooperators. However, an attempt has been made to import Larix under a restricted materials permit. If that cannot be done, it will be necessary to arrange an introduction of the materials through Canada.

With the propagation of most of the larch selections made to date, the project needs to reach a decision regarding the addition of tamarack to the program. Although volume production is less than that of the other larches, tamarack is capable of occupying the more poorly drained, frost prone sites. Hybridization also appears to offer another potential use.

Tamarack has been included in several of the first replicated trials and has shown good early growth and survival. The growth and survival information for the University of Wisconsin Japanese larch provenance trial given in Table 3 includes data on tamarack.

Other species of larch are being considered for inclusion in the project. Before much effort is expended on selection or obtaining selections it will be necessary to outplant the species being considered and evaluate their potential within the site and growing conditions available for the Japanese, European, and hybrid larch. As mentioned in last year's report, the species being considered are Larix gmelini and L. dahurica which occur in East Siberia, North Korea, and northern China. There are few plantings of these materials available in the United States to observe and make selections. Fortunately, a replicated trial was established by IPC in 1961 that included two L. gmelini sources and one L. dahurica source (see Project Report One, page 24). Selections have been made within these sources, and it has been possible to make a comparison with other larch species within the trial.

Seed was collected from L. gmelini and L. dahurica at the Clintonville site. Part of the seed was given to Consolidated Papers and grown in containers. Part of that container stock will be planted by Michigan Technological University this coming spring and part by Consolidated. Both plantings will contribute to the evaluation of the suitability of these materials.

1984 GRAFTING

Of the 135 selections made to date, only 10 trees have not been grafted. Three selections were lost before they could be propagated, leaving 7 selections yet to be grafted. One hundred six clones have been outplanted in the Greenville arboretum, with an additional 18 clones ready to be planted this spring. Figure 1 illustrates the growth of 4-year-old grafts in the arboretum.

A total of 849 grafts were made in 1984 involving 28 L. decidua clones, 9 L. leptolepis clones, and 1 L. gmelini var. gmelini clone. The overall grafting success was 88%, up from last year's 82% but lower than the 1982 rate of 96%.

Figure 1. Four-year-old Japanese larch grafts well established in the Greenville arboretum. A total of 106 larch clones have been planted with an additional 18 clones to be outplanted this spring.

Although we have recommended the use of rootstock that had been potted and grown for one year, circumstances during the 1983 growing season forced the use of freshly potted bareroot stock. As reported at last year's annual meeting, a problem with Fusarium canker developed on the potted understock intended for use and caused large-scale mortality. Fusarium is a fungal disease common in both nursery and greenhouse situations. It can build up under conditions of poor soil aeration and cause both root rot and stem cankers near the root collar area. Because much of the intended rootstock was lost to the disease and most of the survivors were suspect, we were forced to use bareroot stock as the rootstock source. Surprisingly, our grafting success rate was considerably better than anticipated. Of the 12% mortality rate we experienced, 7% was due to understock failure and the remaining 5% due to poorly made grafts or scion failure.

Given the greenhouse space needed and attention required to maintain proper watering of up to 1500 potted larch and then the handling and storage for overwintering, the use of potted larch for understock becomes less attractive. We still believe the best approach is to use established rootstock, particularly when there is a limited amount of scion material available. However, it appears that the mortality rate we experienced during last year's grafting on bareroot stock is acceptable when dealing with a large number of grafts. We have decided to try bareroot stock for the 1985 grafting work along with some previously potted material.

SEED AVAILABILITY

We obtained 23 additional sources of larch seed in 1984 including a recollection of one source that has begun to show good promise in our replicated trials. A total of 52 pounds of larch seed were obtained in 1984 with 20 pounds of that seed purchased by the Wisconsin Department of Natural Resources. Most of the sources were in quantities of 1 kilogram or less. The State of Wisconsin has asked us to arrange for the purchase of an additional 30 pounds of larch seed for 1985.

The cost of the seed we have been purchasing is rather high and the availability, particularly for the provenances we are interested in, has been sporadic. We have been fortunate in having a German cooperator willing to go to some trouble to arrange and acquire a wide range of provenances from behind the iron curtain. These are sources that previously we had been able to acquire only in very modest quantities. With his help we have been able to obtain quantities suitable for seedling production for large plantings.

Because of the seed cost we have had to ask those cooperators requesting seed in quantities greater than a pound to reimburse the project for the cost of that seed. The administrative costs and shipping costs are being underwritten by the project.

The sources we have been and continue to be interested in are the Sudeten provenances in southern Poland and northern Czechoslovakia, the Tatra region in northeastern Czechoslovakia, central Czechoslovakia, and central Poland. Hybrid larch seed is also of great interest but of low availability. We were able to obtain 15 pounds from a registered seed orchard in West Germany but because of poor germination, 15 pounds was equivalent to just 7.5 pounds and represented twice what we ordered to satisfy our specification of a minimum of 40% germination. Larch seed from Austrian provenances is more readily available, but because of our concern with needle cast, we have avoided obtaining more than modest quantities.

The emphasis of seed acquisition has been on European and hybrid larch. Japanese larch continues to be of interest, but because of its apparent susceptibility to frost damage during establishment years, large quantities of seed have not been acquired. Japanese larch does have a place within the scope of the project both for its use in production of hybrid seed and for its use on sites with lessened frost problems. Japanese larch will outgrow European larch and has shown an ability to become established in the northern areas of the Lake

States on a limited scale. Because of the successful Japanese larch plantings in the north, we continue to outplant Japanese larch in our replicated trials and demonstration plantings in an attempt to determine those sources and sites that may be suitable.

We are also attempting to acquire small quantities of Larix gmelini and Dahurian larch seed. These materials have done well in an earlier replicated trial and warrant further evaluation.

LARCH NEEDLE CAST

Potentially the most serious disease problem with various sources of larch is the needle cast problem. The disease is believed to be Mycosphaerella laricina (Hart.) Neg. which is reported to cause defoliation of European and Japanese larch in Europe. Although shown to be a serious problem with French and high elevation Austrian sources of European larch here in the Lake States, it is not considered a problem in Europe.

The sources showing the best resistance here in the Lake States continue to be those from the northern range of European larch, hybrid larch, and Japanese larch. In a recent U.S.F.S. screening test one of the most susceptible sources was western larch (L. occidentalis).*

The project is cooperating with U.S. Forest Service pathologists in their work to evaluate seed source response to the disease. Our participation is primarily one of providing known origin seed lots to be used in a replicated trial on two sites with rather heavy inoculum loads. We provided small quantities of seed from nine sources for use in these trials. The nine sources were

*Michael Ostry, Research Plant Pathologist, North Central Forest Experiment Station, St. Paul, Minnesota.

composed of one *L. leptolepis*, six *L. decidua*, and 2 hybrid larch seed lots. Other trials are being considered to evaluate spore dispersal and effect of light inoculum loads.

Last year's work by U.S.F.S. pathologists involved the outplanting of seedlings adjacent to infected stands. Blocks of container grown stock were also exposed to the inoculum. Because of the time and amount of effort needed to outplant and establish seedlings for these infection studies, the possibility of exposing blocks of containers and then evaluating them in the greenhouse was examined. It appears that this latter approach will be the method used in future studies.

As mentioned previously, the project's contribution will be primarily seed sources, but we have been asked if we could also grow part of the needed seedling material in our greenhouse. Most of these sources will be outplanted during the spring of 1985.

LARCH SEED ORCHARDS - THE EUROPEAN APPROACH

Since seed orchards are such an important part of the Institute larch program, one of the objectives of a trip to Europe this past summer was to visit several European research organizations who have had experience in establishing and managing larch seed orchards.* The researchers and organizations contacted were (1) Dr. Horst Weisgerber at the Forest Tree Breeding Institute in Hann Munden, West Germany, (2) Dr. Helmuth Barner and Dr. H. Keiding at the Danish/FAO Tree Breeding Centre near Humlebaeck, and (3) Dr. G. H. (Heinrich) Melchior at the Institute for Forest Genetics and Tree Breeding in Ahrensburg, West Germany (near Hamburg).

Having had contact with two of the three programs, because of earlier cooperative work with them in the area of aspen genetics, the discussions and visits to field plantings proved very fruitful. The approach was to visit each researcher armed with a long list of questions on soils, sites, establishment, flowering, and care of seed orchards. The hope was to not make the same mistakes they had made and as it turned out their answers proved to be very useful.

DR. HORST WEISGERBER

The first stop was a two day visit near Hann Munden. In the discussions that were an important part of this visit, Dr. Weisgerber indicated grafted clonal orchards were the approach they favored and that they felt both Japanese and European larch seed orchards should have, for genetic diversity, a minimum of 20 clones. They were using a 5 by 10 meter (16.5 by 33 ft) spacing

*Other objectives included visits to hybrid aspen plantings, tissue culture propagation facilities, and forest stands with acid rain problems.

and recommended fertilization (and water when required) soon after planting the grafts to obtain good early growth. When the grafts reach 10 to 15 feet tall, fertilizer, primarily nitrogen, is withheld to reduce growth and encourage early flowering. They established seed orchards (and progeny tests) on old field sites by scalping an area about one meter square and keeping this clean-cultivated for two or three years. They obtained their first seed production at seven to eight years of age.

At the orchards visited, a grass/legume cover crop was used and mowed periodically. They had tried several ways (including topping) of stimulating early and more frequent flowering, with inconsistent results. They were concerned about spacing and had plans for thinning some of their orchards to 10 by 10 meter (33 by 33 ft) spacing. In our discussion on insect and disease problems of larch, Dr. Weisgerber indicated that to date they had not experienced any cone insect or scleroderris canker (*Gremmeniella abietina*) problems. Additionally, Horst indicated neither European larch canker, *Lachnellula willkommii* (Hartig) Dennis, or needle cast disease, *Mycosphaerella laricina* (Hart.) Neg., were considered to be a serious problem. European larch canker apparently reduces growth in susceptible sources but causes little mortality, and growth losses can be reduced by using appropriate geographic sources. As for needle cast, Dr. Weisgerber indicated it was present in stands and plantings of European larch but was not considered a serious problem. They recommended the use of resistant sources, wide spacing, early thinning, and avoiding high humidity situations. One larch progeny test that was visited was a test in which they were using the open-pollinated German source "Schlitz" (a source we are using) as a standard control. Their best full-sib cross in the trial was 5.1 meters (16.8 ft) after six years and had a Sudeten larch as one of the parents. The control cross, Schlitz, averaged just 2.5 to 3.0 meters (8 to 9 ft) at six years. Dr. Weisgerber indicated that their experience with the European x Japanese hybrid larch suggests it has a little poorer form but usually outgrows both of the parent species.

DR. HELMUTH BARNER AND DR. HEINRICH KEIDING

The next visit was to the Danish/FAO Tree Breeding Seed Centre near Humlebaeck, Denmark. This tree breeding station works with a large number of tree species and has the most experience and some of the oldest larch seed orchards in Europe (see Fig. 2). Considerable time was spent discussing the merits of hybrid larch, and both Barner and Keiding were convinced that hybrid larch was the best approach to use in the production of fiber and solid-wood products. Both German and Danish officials are concerned with the purity of hybrid larch seed. Law requires that the purity be specified, and this has influenced seed orchard design. In hybrid seed orchards, the Danes are using a single tested European larch clone as the female parent and a mixture of 15 Japanese larch clones as the male (pollen) parents. Hybrid larch seed is collected from the European larch clone only.

We also spent a considerable amount of time discussing seed orchard establishment. They indicated their most serious mistake was using too close a spacing in early orchards, and as a result they obtained tall trees with narrow, hard to reach crowns and less frequent flowering. Presently, they feel orchard spacings should be 6 x 6 meters or greater. They recommend grafted orchards because of a belief they are obtaining early flowering, and they suggest orchard size should be no less than three hectares (7.4 acres). Additionally, they, like the Germans, believe orchards should be fertilized early to obtain as fast a growth rate as possible and then stop fertilizing and stress the parent tree grafts to increase the frequency of flowering. Barner and Keiding indicated they obtained their first seed production at about eight years and good production from orchards that are 12 to 20 years of age. Their production rates in standard orchards range from 25 to 70 kilograms of seed per hectare (22 to 62 pounds per acre) in good crop years with good years occurring every two to three years. They apparently obtain less hybrid seed per hectare and cited figures of 6 to 17 kilograms per hectare per year for hybrid orchards. Figure 3 illustrates a Japanese larch seed orchard at a spacing of about 25 x 25 feet.

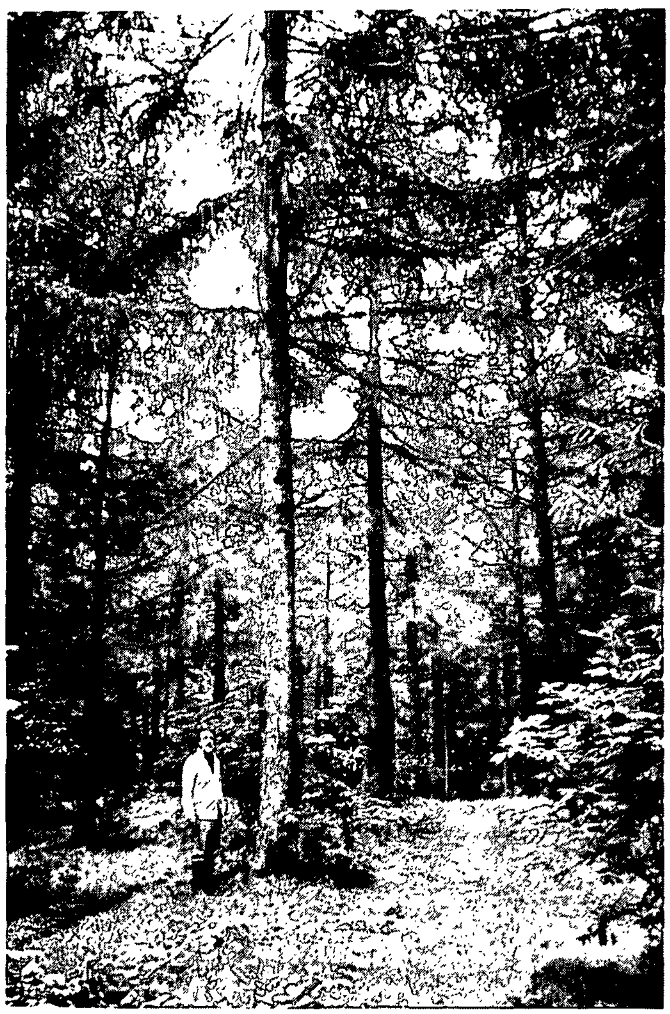

Figure 2. The oldest European x Japanese hybrid larch seed orchard in Europe is located near Humlebaek, Denmark. This 41-year-old orchard has one clone of European larch (Tyrol origin) that is being pollinated by seedlings from a full-sib Japanese larch cross. Dr. A. H. Keiding is shown in the foreground.

Figure 3. The grafted 22-year-old Japanese larch clonal seed orchard shown is located near Humlebaek, Denmark. Dr. A. H. Keiding is shown in the foreground.

Some time was spent discussing methods of stimulating flowering and the possible approach of producing and storing pollen and then using it to supplement the normal supply (and improve seed set). Drs. Barner and Keiding indicated they had tried banding, topping, root pruning, etc., with inconsistent results. They also indicated pollen production was low and the pollen difficult to handle, and as a result they were not enthusiastic about the "supplemental pollen" technique. We also discussed insect and disease problems, and Barner and Keiding reported they were having no problems with cone insects or scleroderris canker and only minor needle cast and European larch canker problems. As a result of this day of discussions, a hybrid larch seed orchard design was developed for use in Project 3409. Figure 4 illustrates the hybrid larch orchard that resulted which utilizes four clones of European larch, 15 clones of Japanese larch, and a 30 by 30 foot spacing. This orchard, which is a variation of one by Barner and Keiding, is a way of producing high purity L. eurolepis seed (seed collected from European larch only). Additionally, by collecting seed from the Japanese larch parent trees, high quality seed that is a mixture containing mostly Japanese larch seed with some "leptolepis x decidua" seed will be obtained.

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	X_1	0	X_1	0	X_1	0	X_1	0	0	X_2	0	X_2	0	X_2	0	X_2	0
0	X_1	0	X_1	0	X_1	0	X_1	0	0	X_2	0	X_2	0	X_2	0	X_2	0
0	X_1	0	X_1	0	X_1	0	X_1	0	0	X_2	0	X_2	0	X_2	0	X_2	0
0	X_1	0	X_1	0	X_1	0	X_1	0	0	X_2	0	X_2	0	X_2	0	X_2	0
0	X_1	0	X_1	0	X_1	0	X_1	0	0	X_2	0	X_2	0	X_2	0	X_2	0
0	X_1	0	X_1	0	X_1	0	X_1	0	0	X_2	0	X_2	0	X_2	0	X_2	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	X_3	0	X_3	0	X_3	0	X_3	0	0	X_4	0	X_4	0	X_4	0	X_4	0
0	X_3	0	X_3	0	X_3	0	X_3	0	0	X_4	0	X_4	0	X_4	0	X_4	0
0	X_3	0	X_3	0	X_3	0	X_3	0	0	X_4	0	X_4	0	X_4	0	X_4	0
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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4. Illustrated is a four clone European x Japanese hybrid larch seed orchard. X_1 through X_4 are the four European larch clones. The 0's are the locations of a random mixture of 15 Japanese larch clones. The planned spacing is 30 x 30 feet and the area required (with border) is 6.5 acres.

DR. HEINRICH MELCHIOR AND ASSOCIATES

During a two day visit to Ahrensburg, in addition to discussions with Dr. Melchior, the visit created the opportunity of meeting with Dr. Otto Mohrdiek, Dr. H. Reck, and two Ph.D. students who were working on forest genetics problems. The discussions with Dr. Melchior and the others tended to confirm the information obtained at the other two tree breeding stations. They were confident that hybrid larch were superior to nonhybrids in growth rate and only occasionally were specific European or Japanese larch sources as rapid growing as the hybrids. Dr. Mohrdiek was less enthusiastic about larch hybrids, apparently because of the difficulty of obtaining high purity documented sources.

Seed orchard design discussions brought to the forefront that German law requires that the percent hybrid seed in seed lots be specified and that because this is difficult to do (Barner said they can tell by looking at Fall needle color and needle drop), they are preoccupied with this requirement in designing their seed orchards. Melchior believes that isozymes will eventually be the method used to estimate the percent hybrid seed in a seed lot. Melchior and associates were nonspecific about seed orchard spacing, but because of the high value of land, they appeared to favor spacings that were closer than the Danes. They indicated they favored the use of clonal orchards and felt that a minimum of 20 clones per orchard were required. Additionally, they felt the Danish approach to establishing hybrid orchards was the appropriate method for obtaining high purity hybrid seed. Most of the soils they have available for use in the Ahrensburg area are heavier (silt and clay loams) than normally available in the Lake States, and they apparently have not considered fertilization and stressing procedures to stimulate more frequent flowering. Their comments in our discussion of insect and disease problems indicated they were not concerned about scleroderris canker and felt that European larch canker and needle cast disease were important but not serious problems.

UNITED STATES VS. EUROPEAN SEED ORCHARDS

Larch seed orchards have been established by the states of New York and Pennsylvania, and these orchards have started producing seed. Visits to New York State orchards near Saratoga Springs, N.Y. and discussions with the State of Pennsylvania* indicate they are using the grafted clonal seed orchard approach but are using less than the recommended number of clones. Also, they have used within and between row spacings of 18 to 20 feet and are experiencing spacing problems. New York State nurserymen indicated the close spacing appears to be reducing seed production, and as soon as budget restrictions will allow, they plan to thin their older orchards. Budget restrictions have also resulted in minimal care of their seed orchards, and there appear to be several ways production could be increased. Discussions with John Solan and Kurt Swartz made it clear that in the future, larch orchards would be on upland sandy soils and at a minimum spacing of 25 x 25 ft. They expect their first major seed production at 12 to 14 years, with good crops every four to five years. They also had an interesting suggestion (which they had tried in a preliminary way) and this was to wait until the first crop year and then top the trees (modestly) at the time of cone collection. The objectives were to speed cone collection, produce a multiple top, reduce height growth, and stimulate flowering.

The State of Pennsylvania Japanese larch seed orchards have an interesting record of seed production. They have one ten-acre grafted orchard

*Jack Winieski, Forest Geneticist with the Bureau of Forestry, Harrisburg, Pennsylvania.

that flowered and produced a good cone crop in 1980 at age 14. Seed production was good again in 1984 with a production of 200 bushels of cones (125 lb of seed/10 acres). At age 18 their parent trees were about 50 feet tall. Crown closure has made it necessary to thin every fourth row, and they anticipate that they will need to thin again in the near future.

SUMMARY

Based upon United States and European seed orchard experience, the following are some of the major conclusions reached concerning the establishment of larch seed orchards in the Northeast, Central, and Lakes States Regions.

1. Type - Use grafted clonal orchards with a minimum of 20 to 30 clones. Fewer clones are required if progeny tested clones are used. Progeny testing could result in the roguing of up to 1/2 of the original clones.

2. Hybrid Orchards - F-1 hybrid orchards should follow the Danish approach of using grafted clones but employing one to four high quality European larch clones and a mixture of 10 to 15 Japanese larch clones.

3. Location - Orchards, particularly Japanese larch, should be located as far south as possible, to take advantage of the Great Lakes or ocean effects when possible, and be located on upland, well-drained medium-textured sites, with level to north aspects (not south aspects).

4. Spacing - Orchards should be planted at a minimum spacing of 25 x 25 feet with a 30 x 30 foot spacing preferred.

5. Care - Orchards should be maintained free of weeds for the first two to three years, staked to maintain good form, protected from rabbits and mice, and fertilized (and irrigated when required) to maximize early growth.

After about six years, nitrogen fertilization should be reduced and modest top pruning tried at the time of the first major crop year (optional). Legume/ grass cover combined with mowing is recommended after year six.

6. Stimulation of Flowering - No method is presently recommended because of inconsistent results. Moisture stress during hot, dry summers appears to be the most often reported condition for good flower and cone production. Avoiding heavy-textured soils as orchard sites, reduction of nitrogen fertilization, and some topping and shaping to increase crown area may be useful in increasing cone production.

7. Seed Production Rates - Reported seed production rates for larch are variable, but it appears good seed years in well managed orchards can be expected every three to five years (after age 14) and rates of production will be from 8 to 15 pounds of seed per acre for standard orchards. Hybrid seed orchards can be expected to produce 10-30% less seed than the standard orchards.

STATUS OF PROJECT 3409 SEED ORCHARDS

Three seed orchards are planned for establishment this coming spring. Based on cooperator discussions during last year's annual meeting, the first orchards will be planted with only half of the total material needed. With that approach, several cooperators will have an opportunity to establish materials in a shorter period of time than if entire orchards were being put in at one time. The remaining portions of the orchards will be filled in 1986.

The first orchards will be composed of 20 clones of European larch from Sudeten, Polish, and Czechoslovakian origins. When the orchards are completed, a total of 400 positions will be occupied (20 clones x 20 ramets/clone). As described in Report One, page 12, the seed orchard design selected is computer generated and maximizes outcrossing. This particular design, known as a permutated neighborhood design, isolates a ramet of a clone from other ramets of the same clone and minimizes the number of times two clones are planted adjacent to each other. An illustration of the design for the first orchards is given in Fig. 5.

	COLUMN																			
ROW I	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	6	7	8	9	5	7	10	8	5	6	9	10	11	4	12	13	11	3	12	14
2	4	13	14	15	3	16	2	17	18	15	2	16	18	17	1	19	20	6	5	4
3	9	12	2	6	11	12	4	9	7	3	8	14	13	7	5	10	14	8	1	10
4	16	19	1	18	13	20	15	1	11	19	4	6	15	9	2	3	17	9	15	13
5	7	15	8	10	5	17	8	16	12	17	20	5	1	12	16	4	11	18	7	6
6	3	14	20	4	19	2	7	13	10	15	18	11	10	17	6	13	5	12	19	3
7	2	9	11	16	3	9	14	4	5	2	8	7	14	19	15	20	1	8	14	11
8	10	12	6	1	18	20	11	6	19	3	9	12	13	3	2	9	10	16	4	13
9	15	5	8	7	15	12	16	1	17	14	16	6	5	4	11	17	13	3	7	17
10	16	17	14	10	19	2	13	18	20	10	11	1	8	20	12	14	6	15	2	5
11	6	2	11	4	5	8	3	4	9	7	2	18	17	10	13	1	19	9	20	16
12	18	7	1	12	18	14	6	19	16	8	5	12	9	3	15	5	4	11	10	3
13	13	19	9	15	16	17	7	2	1	15	20	13	7	14	8	17	18	13	8	1
14	11	17	10	20	3	4	9	11	18	4	10	6	1	11	16	9	3	12	6	7
15	3	5	2	8	19	5	13	12	14	17	16	8	15	18	13	10	14	19	15	16
16	6	4	7	1	14	18	20	6	7	2	9	5	12	4	6	2	5	11	17	9
17	14	16	12	13	10	15	8	3	1	15	18	14	17	20	3	7	1	18	4	10
18	19	18	11	20	17	2	19	16	13	20	19	6	1	8	11	12	9	13	2	7
19	3	2	5	6	4	1	9	10	11	4	7	10	15	5	16	17	19	8	14	16
20	12	8	15	19	12	3	18	17	14	2	8	9	12	4	14	18	6	11	5	17

Figure 5. The design shown will be used for the first 20-clone European larch seed orchards. The positions for the ramets of each clone are computer generated and maximize outcrossing. The ramets from any given clone are isolated from other ramets of the same clone by at least two positions. The number of times different clones are planted next to each other is also minimized. The 400 position orchard illustrated requires 8.3 acres.

Based on observations of European and U.S. orchards and comments by orchard managers, the spacing within our orchards will be 30 feet x 30 feet. As mentioned in the previous section of this report, one of the main problems orchard managers are facing is spacing that is too tight. Our original intention of using a 25 foot spacing was increased to 30 feet because of these comments.

The orchards planned for this spring will be established by Consolidated Papers, Inc., Wisconsin Department of Natural Resources, and the Michigan Department of Natural Resources. These will be half orchards with the remaining half planted as material becomes available. Material for two more half orchards will be available for the spring of 1986. We have requests for 15 orchards, and because it is not possible to establish all of them at one time, it was decided that those cooperators expressing a desire for immediate orchard materials and with prepared sites available would receive the first orchards. Cooperators desiring orchards for 1986 should make their request known as soon as possible.

REPLICATED FIELD PLANTINGS

MOSINEE PAPER CORPORATION

The Mosinee replicated trial was the first trial planted in the larch project. It is located on a sandy, dry, old-field site that had been planted with red pine which had partially failed. The site was prepared by spraying with glyphosate followed by plowing and disking. The stock was container grown and, in hindsight, was too succulent for outplanting. A combination of bare soil and succulent stock produced a severe problem with groundline injury that resulted in high mortality throughout the trial. Several materials had replacements planted in August, 1981, two months after the initial planting.

Frost damage to the Japanese and hybrid sources of larch was noted the following spring (1982). A continuing frost problem with Japanese larch led to the replacement of one of the most severely damaged sources (XLL-1-79) with a *L. decidua* source. An additional problem with pocket gophers developed and increased in severity over the past two years to the point where high mortality within all materials is occurring. Figure 6 illustrates the type and extent of damage the gophers are producing. The damage and mortality were so widespread this past year that there is little chance any of the sources will survive in sufficient numbers to provide useful information. A decision has been made to terminate the trial if the gophers cannot be controlled.

CONSOLIDATED PAPERS, INC.

The second trial established in the larch project was put in by Consolidated Papers near Argonne, Wisconsin in August of 1981. The trial was planted with container stock on a medium-quality hardwood site. The area was an old-field with a dense cover of quack grass which was treated with glyphosate one week prior to planting. Vegetation control was marginal and heavy competition developed. Glyphosate was applied again in 1982 using a directed spray and shielding the larch.

Figure 6. Widespread damage by gophers to Mosinee Paper Corporation's replicated larch trial near Gordon, Wisconsin has led to the decision to terminate the trial if further damage cannot be controlled. Root systems on many individuals were severely damaged and above ground injury was also extreme with a number of individuals severed.

Japanese larch and to a lesser extent the hybrid larch have been repeatedly damaged by frost. Replacements were made but continued mortality led to replacement of two sources of Japanese larch with European larch. Table 1 presents growth and survival data for the past three years. The best material is XLD-3-79, a seed source obtained from a West German seed orchard composed of Sudeten and northern Czechoslovakia selections. Figure 7 shows one of the better XLD-3-79 individuals. The hybrid material XLD-LL-1-79 had frost damage during the first growing season, but after replacements were made no serious further damage occurred. The low height growth shown for the hybrid was the result of averaging the replacement stock heights with the heights of the surviving individuals. The tamarack control source has done well (Fig. 7), having no frost problems and good growth and survival.

Table 1. Consolidated Papers - Replicated Larch Trial.

	1982		1983		1984	
Material	Av. Ht., feet	Survival, %	Av. Ht., feet	Survival, %	Av. Ht., feet	Survival, %
XLD-3-79	1.6	88	2.9	86	4.1	86
XLD-5-79	1.4	93	2.4	99[c]	3.5	94
XLD-6-79	1.2	74	1.9	70	2.5	66
XLL-1-79	1.1	100	1.6	77	1.6	64
XLD-LL-1-79	1.1	52	1.8	99[c]	2.4	99
XLTK-5-80	1.5	94	2.5	97	3.5	96
XLD-1-81	--[a],	--	1.9[b]	99	2.6	99
XLD-5-82	--[a]	--	0.7[b]	100	0.7	83

[a]Planted in 1983 as replacements for low survival Japanese larch sources.
[b]First year growth and survival.
[c]Replacements made.

The trial, with the exception of the two replacement materials, is doing well and appears to be above the grass competition.

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Figure 7. Illustrated are two of the best materials in Consolidated Paper's replicated larch trial near Argonne, Wisconsin. The material on the left is XLD-3-79, a European larch source composed of Sudeten and northern Czechoslovakia origins, and averages 4.1 feet. The material on the right is XLTK-5-80, a tamarack source from Upper Michigan, and averages 3.5 feet.

SCOTT PAPER COMPANY

The Scott replicated trial was the first trial with bareroot stock. With the exception of a trial established this past year, all others have been put in with container grown stock. The 2-0 bareroot stock provided for this trial was grown at the IPC Nursery at Greenville, Wisconsin, and shipped to Maine for planting the spring of 1982. The material included four sources of European larch, two sources of Japanese larch, one source of hybrid larch, and one local source of tamarack seedlings grown in Maine.

The planting site had been under cultivation and was disked prior to planting. Returning competition was controlled by a directed spray of glyphosate applied in 1983. Some mortality has been attributed to the glyphosate treatment.

Growth during 1984 was good, although somewhat less than expected. Larch tends to have moderate growth during the first 2-3 years of establishment and then can be expected to grow at rates of two feet or more per year on average larch sites. The growth and survival information given in Table 2 seems to indicate that the establishment period is over. It is expected that growth rates in this trial should begin to increase during the next growing season.

Table 2. Scott Paper Co. - Replicated Larch Trial[a].

	1982		1983		1984	
Material	Av. Ht., feet	Survival, %	Av. Ht., feet	Survival, %	Av. Ht., feet	Survival, %
XLD-1-79	1.2	95	2.2	92	3.1	90
XLD-2-79	1.4	81	2.5	73	3.4	59
XLD-3-79	1.7	96	2.7	92	3.8	89
XLD-6-79	1.4	90	2.5	77	3.7	70
XLL-2-79	1.2	84	2.5	71	3.7	67
XLL-3-79	1.6	83	3.2	75	4.3	72
XLD-LL-1-79	1.8	89	3.3	97	5.1	94
Tamarack	<1.0	84	1.3	60	2.5	53

[a]Measurement data provided by David Maass.

The hybrid material XLD-LL-1-79 (see Fig. 8) and the Japanese material XLL-3-79 continue to be the best materials in the trial. An analysis of variance and Duncan's Multiple range test indicated no difference between these two materials in height growth. Both of these sources are from clonal seed orchards composed of plus tree selections. The good growth of Japanese larch is not unexpected. Numerous comments in the literature and our own observations indicate Japanese larch will outgrow European larch on sites where frost is not a problem.

Figure 8. One of the best hybrid larch individuals in Scott Paper Company's replicated larch trial near Fairfield, Maine. At the end of 3 years the hybrid source, XLD-LL-1-79, averaged 5.1 feet in height and 94% survival.

The trial, at the end of three years, has the best growth and survival of the replicated trials established. It is also the only trial established with bareroot stock (with the exception of the WDNR trial put in this past spring). It is still believed that a comparison of bareroot larch stock and container grown larch stock needs to be made. The bareroot vs. container trials planned for last year were not planted due to the loss of the bareroot stock in the IPC Nursery from frost heaving. An attempt will again be made to produce the bareroot stock this coming year for a comparison planting in 1986.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

A replicated trial was planted this past spring on Wisconsin state forest land near Boulder Junction. The site was previously planted to jack pine and clearcut the winter of 1983. The ground cover was scattered oak, red maple, paper birch, hazelnut, bracken fern, blackberry, and blueberry. The site was prepared with a Brakke scarifier. The trial tests eight materials in four replications. The materials include four L. decidua, two L. leptolepis, and 2 hybrid sources. The stock was hand planted on 10 foot by 10 foot centers which resulted in most of the stock being planted off of the scarified strips.

The site quality of the area is about as low as intended for larch establishment. It was felt that larch growth on lower quality sites needed to be evaluated to begin determining where larch could best be utilized in planting programs. Japanese larch and to a lesser extent hybrid larch have demonstrated an ability to produce acceptable growth on poorer quality, dry sites where frost is not a major problem. The growth of European larch under those conditions has not been evaluated to the same extent.

Survival at the end of the first year was very good, ranging from 88% to 100% with six materials over 95%. Height growth was minimal, but lateral growth and vigor appeared to be good. The best material was the hybrid source XLL-LD-2-79 (Fig. 9). Growing conditions were good last year, and it is hoped the materials are in condition to do well this year. Animal pressure may occur due to the type of cutting that produced numerous small openings in a conifer plantation. However, deer pressure to the larch plantings we have observed has been almost nonexistent, an unexpected but welcome situation. The one problem that may develop and will be closely watched for is the incidence of Armillaria mellea (Vahl.: Fr.) Kummer root rot. The prevalence of oak stumps throughout the trial may cause problems with Armillaria, but not to any greater extent than would be expected for other conifers.

Figure 9. The seedling illustrated is a one-year-old hybrid larch, XLL-LD-2-79, in the Wisconsin DNR replicated trial near Boulder Junction, Wisconsin. At the end of the first year it averaged 2.1 feet in height and 100% survival.

STARKS

During our parent tree selection work we became aware of two Japanese larch provenance trials established by the University of Wisconsin at Starks, Wisconsin, near Rhinelander. The trials were part of the NC-51 study (1) initiated in 1958 and planted in 1960 and 1961. We made a total of five selections from the two trials (Fig. 10). During the selection process it was apparent that the trials should be measured for growth and survival information.

Figure 10. A 24-year-old Japanese larch selection from one of the University of Wisconsin provenance trials at Starks, Wisconsin. The tree is 46 feet in height and 7.9 inches DBH. Origin is the Akaishi Mountains in Japan (Table 3).

The 1960 planting was at 25 years of age and had a source of tamarack as one of the six materials. The other five materials were Japanese larch. The trial was hand planted with 2-0 bareroot stock at 8 x 8 foot spacing. There were 12 replications of four tree plots (2 x 2) with a border row of tamarack around the trial. Table 3 presents the growth data for ages 4, 10, and 25 years. At 25 years there were no significant differences in height and diameter growth within the Japanese larch sources. The tamarack source had height and diameter growth significantly lower than the Japanese larch (Fig. 11). Differences between sources were more evident in survival. Three of the sources (4, 22, 24) had survival ranging from 31% to 56%. The remaining three sources (tamarack, 12, 15) had survival ranging from 79% to 88%. Early information for the trial indicates that frost damage occurred to all materials, with the tamarack source being the least damaged and the Japanese larch provenance No. 4 being the most damaged. All of the mortality occurred before age 10. Our experience with trials and plantings indicates that frost damage at early years is the primary cause of mortality to Japanese larch. Those individuals that survive and grow tend to get above (outgrow) further frost injury. The two provenances with the best survival, No. 12 and 15, are high elevation sources which may have contributed to their ability to withstand the frost damage and suggests that additional high elevation sources should be tested.

Although the tamarack source had significantly lower height and diameter growth than the Japanese larch sources, survival was not different from the best two Japanese sources. This is again in line with our previous observations of tamarack growth. Although the site on which the trial is planted has a sand texture and an acceptable nutrient level, the limiting factor is moisture. The growth differential apparent between tamarack and Japanese larch in this

Table 3. Starks Japanese Larch Provenance Trial - University of Wisconsin, Rhinelander, Wisconsin.

Material	Schmalenbeck[a] Number	Elevation, feet	4 Years		10 Years		25 Years		
			Av. Ht., feet	Survival, %	Av. Ht., feet	Survival, %	Av. Ht., feet	Av. DBH, inches	Survival, %
Mt. Nantai	15	5600	4.9	95	18.5	92	46.8^{x}	7.3^{x}	88^{z}
Mt. Azusa	4	4900	4.1	80	16.5	46	46.3^{x}	7.3^{x}	44^{xy}
Akaishi Mts.	12	6600	5.3	95	17.7	83	48.2^{x}	7.8^{x}	83^{z}
Hida Mts.	22	4600	4.1	55	16.0	31	46.0^{x}	7.2^{x}	31^{x}
Hida Mts.	24	4600	4.1	82	16.0	57	46.9^{x}	7.7^{x}	56^{y}
Toumey Nursery[b]	--	--	3.9	85	15.2	77	40.3^{y}	5.4^{y}	79^{z}
"F" test[c] for treatments	--	--	--	--	--	--	S	S	S

[a]Schmalenbeck number - provenance identification for International Japanese larch provenance trial.

[b]Tamarack.

[c]Analysis of variance "F" test for treatments. "S" indicates values significant at the 5% level of probability.

^{xyz}Duncan's Multiple Range Test was calculated when "F" test values for treatments were significant. Values followed by a common superscript letter are not significantly different.

planting is present in other plantings with improved site quality. Tamarack does have an advantage over the other larches in poorly drained, frost prone areas. Growth rate and perhaps wood quality may be improved through hybridization.

Figure 11. 24-Year-old tamarack growing in one of the University of Wisconsin provenance trials at Starks, Wisconsin. The material averaged 40.3 feet in height and 5.4 inches DBH, significantly lower than the five Japanese larch sources in the trial (Table 3).

DEMONSTRATION FIELD PLANTINGS

CONSOLIDATED PAPERS, INC.

A planting of hybrid larch made in 1981 near Winchester, Wisconsin, was one of the first cooperator plantings established. Early growth and apparent survival was disappointing. The stock was container grown and hand planted on an aspen-balsam fir site that had been cut the summer before and site prepped in the fall by raking a small amount of slash. There were open areas on the site at the time of planting and Consolidated's records indicate that the site always had openings. Much of the site is poorly drained.

A considerable amount of aspen suckering developed on about one-third of the site, and the larch planted in this area were never able to compete. Those areas of the site where suckering was reduced and drainage was good had good larch survival and growth. Observations of growth during 1984 indicated that survival was considerably better than earlier observations indicated. The best stems have heights of 6-7 feet with most of that growth occurring in the last two growing seasons (Fig. 12). Competition from ferns, broadleaf weeds, and aspen suckers restricted early growth. After a slow establishment period, good growth developed and there appears to be sufficient stocking to avoid replanting. This site would be a good candidate for planting tamarack in the more poorly drained areas and for planting hybrid or European larch on the better drained areas.

Figure 12. Four-Year-old container-grown hybrid larch growing on Consolidated Paper's lands near Winchester, Wisconsin. After a slow establishment period, the material is now growing well, with a number of individuals having annual growth of three feet.

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

A planting of European, Japanese, and hybrid larch was put in in May, 1979, on state owned land near Covington, Michigan. The area had a medium quality hardwood stand with excessive mortality due to what was believed the effects of drought. The stand was clearcut and planted with 2-0 bareroot stock that was quite large, requiring on-site root pruning. It is believed the condition of the stock and inexperienced planters contributed considerably to the high mortality that occurred. Frost damage was noted in successive years and also contributed to the low survival.

There is a pocket of Japanese larch on the site where the survival is good. This is somewhat surprising given the problem with frost damage that is associated with the use of Japanese larch. Observations of Japanese larch in other plantings continue to indicate that frost is a factor limiting establishment. However, there is some indication that higher elevation Japanese larch sources may be capable of overcoming early frost damage. The origin of the Japanese larch seed source used (aside from New York State) in the Covington planting is unknown.

Much of the survival throughout the plantation tends to be along the edges of skid trails. No clear reason for this situation is evident but may be related to lessened competition or some planting factor due to accessibility for the tree planters.

MICHIGAN TECHNOLOGICAL UNIVERSITY - HERBICIDE TRIAL

An opportunity to evaluate the effects of a number of chemical site preparation treatments on planted larch arose after Michigan Tech treated an area on the Baraga Plains near L'Anse, Michigan. Their herbicide study was designed to evaluate the conversion of low quality hardwood stands to productive conifer plantations. Eight herbicides were applied at different levels in the fall of 1983 to a site that had been whole-tree harvested in May, 1983.

We were asked if larch stock was available for inclusion in the study along with red and jack pine. Three sources of material were available: hybrid larch, Sudeten larch (European), and Japanese larch. The majority of the stock was hybrid, with the small quantity of the remaining two sources (Sudeten and Japanese) of larch planted on either side of the treated area. The stock was planted in May, 1984, one year after treatment.

Survival after one year was very good for the larch, approaching 90%. Growth was moderate but stock vigor appears to be good. Unfortunately, the survival of the red and jack pine was very poor. The reasons for this mortality are not clear. The same crew that planted the larch planted the pine and there was no neglect of the stock after pickup.

The pine will be replanted this spring. The opportunity to evaluate the effect of the chemical treatment still remains for the larch but has been lost for the pine. A description of the effect of the various chemical site preparation treatments should be available for discussion next year.

CONVERSION PLANTING COMPARING BAREROOT VS. CONTAINER PLANTING STOCK

The planned 1984 trials to compare site preparation treatments and planting stock had to be delayed. The bareroot material was being grown as 2-0 stock in the IPC nursery but was lost to frost heaving during the winter and spring of 1983. The heavy soils at the IPC nursery make it very difficult to avoid the conditions leading to frost heaving. To get around the problem, we plan to start seedlings in the greenhouse and grow them for 8-12 weeks, then outplant to a nursery lineout after the danger of spring frosts. It is hoped that a plantable one-year-old seedling can be produced in this manner.

The difficulties encountered in establishing a number of the first replicated trials and demonstration plantings using container stock appeared to be in part due to the stock. There were site situations where it was believed that bareroot stock would have been in a better position to compete with the surrounding vegetation. We have noted plantings of container larch where good growth did not occur until three years after planting. The intention is not to build a case for the use of one type of stock over another but rather to investigate site and site preparation conditions best suited for each stock type.

HERBICIDES SUITABLE FOR USE WITH LARCH SPECIES

Larch establishment has been somewhat inconsistent due partly to poor site preparation, the lack of release herbicides, and/or planting stock condition. The lack of a release herbicide has hampered growth and survival on sites where competing vegetation is the limiting factor. Our observations continue to indicate that a modest amount of shading during the first year is beneficial. Broadleaf herbaceous and minor hardwood competition appear to be tolerable. It is the situation, typically affecting many plantations, where competition limits moisture that larch survival is reduced. The other situation affecting growth and ultimately survival is dense hardwood competition, particularly from cherry and aspen (light and moisture is limiting). If competition is dense and grows rapidly, only scattered larch seedlings in favored positions are capable of catching up and growing rapidly enough to survive. We have observed a number of plantings where hardwood competition developed more quickly than anticipated and the seedlings were overtopped. Larch seedlings survived for several years under those conditions and appeared capable of good growth if released.

An effective release chemical, compatible with larch, for controlling hardwoods is still not available. A method utilizing Velpar L in spot treatments between rows, where developing larch root systems will not intercept the column of Velpar, appears to be feasible. Release from grass competition is less of a problem. Fusilade (ICI Americas Inc.) and its numbered formulation PP005, are being tested for forestry use and have produced no damage to larch in the nursery, arboretum, and field plantings. Simazine, a commonly used agricultural herbicide, is also suitable at lower rates (2-3 lb) but has produced damage at rates of 5 lb/acre. Oust may be suitable for release from grasses and broadleaves at rates of 2-4 oz applied preemergent, but results are still inconclusive. Goal 2E is being used routinely in the nursery and arboretum for broadleaf weed control and, although not labeled for forestry field use, can be used in seed orchard establishment.

Work with release chemicals and rates will continue, but it is felt the best solution is in good site preparation. A number of establishment regimes used for pine, larch, and aspen have been observed. The better treatments combined both chemical and mechanical approaches. One of the treatments that looks promising is mechanical scarification combined with either a chemical spot treatment with Velpar L or banding with Oust at the time of scarification. Chemical site preparation alone has looked promising and will be tested further this coming year with Oust, Garlon, Velpar, and Arsenal. The intention is to place a replicated trial on a recent cutover hardwood site that is considered appropriate for conversion to conifers. Treatments will be spring applied with planting the following spring.

Although there has been concern with establishment problems, it is felt that treatments suitable for pine and spruce (with the exception of chemicals known to damage larch) are also suitable for larch. The "old horse," planting stock condition, has been flogged many times and often unjustly, but still remains a factor regardless of species. Larch is a new planting option and is also new to containers and bareroot operations. Experience has shown that cultural conditions for larch are different from pine and spruce. A number of early planting failures can be directly attributable to stock condition that occurred from inexperience in growing and handling larch. Methods have been modified several times, particularly for container production, and the stock quality available now is considerably better than the first material produced.

It is believed that with the bareroot and container stock now available, along with increased knowledge of establishment methods and site requirements, plantation establishment will be as successful as other conifer plantings.

WOOD QUALITY EVALUATION

SELECTED TREE DATA

Wood density (specific gravity), fiber length, and extractives (alcohol-benzene and hot water) are considered to be wood properties important to the pulp and paper industry. It is equally important to recognize that by selecting trees for these properties, the results will have beneficial effects on the wood quality of trees used for solid wood products.

With the need to maintain adequate wood quality, the establishment of base lines for the evaluation of selected trees is underway. The procedure used has been to measure the wood properties of selected trees and trees harvested for other purposes and add these data to the information already available.

Specific Gravity

The specific gravity values used in comparing parent trees are based upon ovendry weight/green volume measurements using two breast high 10-mm increment cores from each tree. Although complete cores are also used in measuring selected tree specific gravity, comparisons between parent trees are based on rings 14-16. For most of the trees, except those over 25 years of age, rings 14-16 are located in the sapwood and contain only small amounts of extractives. For trees older than 25 years of age, extractive levels should be taken into consideration when evaluating the specific gravity of individual trees. Table 4, which compares the wood properties of Japanese and European larch, illustrates the modest wood density advantage of European larch and gives the variation encountered among individual trees.

Table 4. Base-line wood quality values for Japanese and European larch.

Wood Property	Japanese Larch	European Larch
Specific Gravity		
Age 15	0.393 (35)[a]	0.429 (40)
$s/\sqrt{n}$	0.007	0.006
	*****	
Fiber Length		
Age 15	3.2 (28)	3.0 (37)
$s/\sqrt{n}$	0.07	0.05
	*****	
Extractives		
Alcohol-benzene, %	3.6 (30)	2.9 (40)
$s/\sqrt{n}$	0.23	0.20
Hot water, %	7.0 (30)	6.1 (38)
$s/\sqrt{n}$	0.48	0.37

[a]Number in parentheses gives the number of trees used in obtaining the indicated means.

Fiber Length

Fiber length measurements were made using the same breast high increment core samples used for specific gravity. Fiber length measurements were made on rings 11-15 and on 14-16 by projecting and measuring 600+ fibers (tracheids) for each sample. The data obtained on selected trees were used to establish preliminary base-line values for comparing parent trees. This age-15 information is summarized in Table 4. To better visualize how a newly selected tree compares with the age-15 base-line information from earlier selected trees and trees used in pulping studies, Fig. 13 was prepared. Plotting the value for a newly evaluated tree on the base-line figure provides an appropriate basis for comparison. When trees are marginal in other important characteristics (growth rate, form, potential disease problems, etc.), lower-than-average fiber length may result in elimination of a selected parent tree from the program. Our data to date indicate that age-15 fiber length of Japanese larch is a little longer than European larch (3.1 mm vs. 3.0 mm). The differences between species do not appear to be significant, and it appears possible to combine the data for the two species and establish a single base line.

Extractives

Extractives levels are important because they influence specific gravity values, pulp yield, and bleaching chemical requirements (particularly hot-water extractives). Alcohol-benzene extractives and hot-water extractives were determined on the interior ten rings of breast high 10-mm increment core samples and as such represent values for heartwood for trees of age 15 or greater. TAPPI Method T 204 os-76 was used for alcohol-benzene extractives, and a modification of the same method was used for hot-water extractives. Separate samples were used for each determination, and the results obtained were expressed as the percent dry weight. Table 4 also summarizes the extractives data. Japanese larch has a higher level of both alcohol-benzene extractives and hot-water extractives. The levels reported continue to be less than reported for older, slow-growing trees. There also appears to be some evidence that extractive levels in heartwood are age dependent (increase with tree age), and some method of adjusting for tree age may be required when comparing parent tree extractive levels.

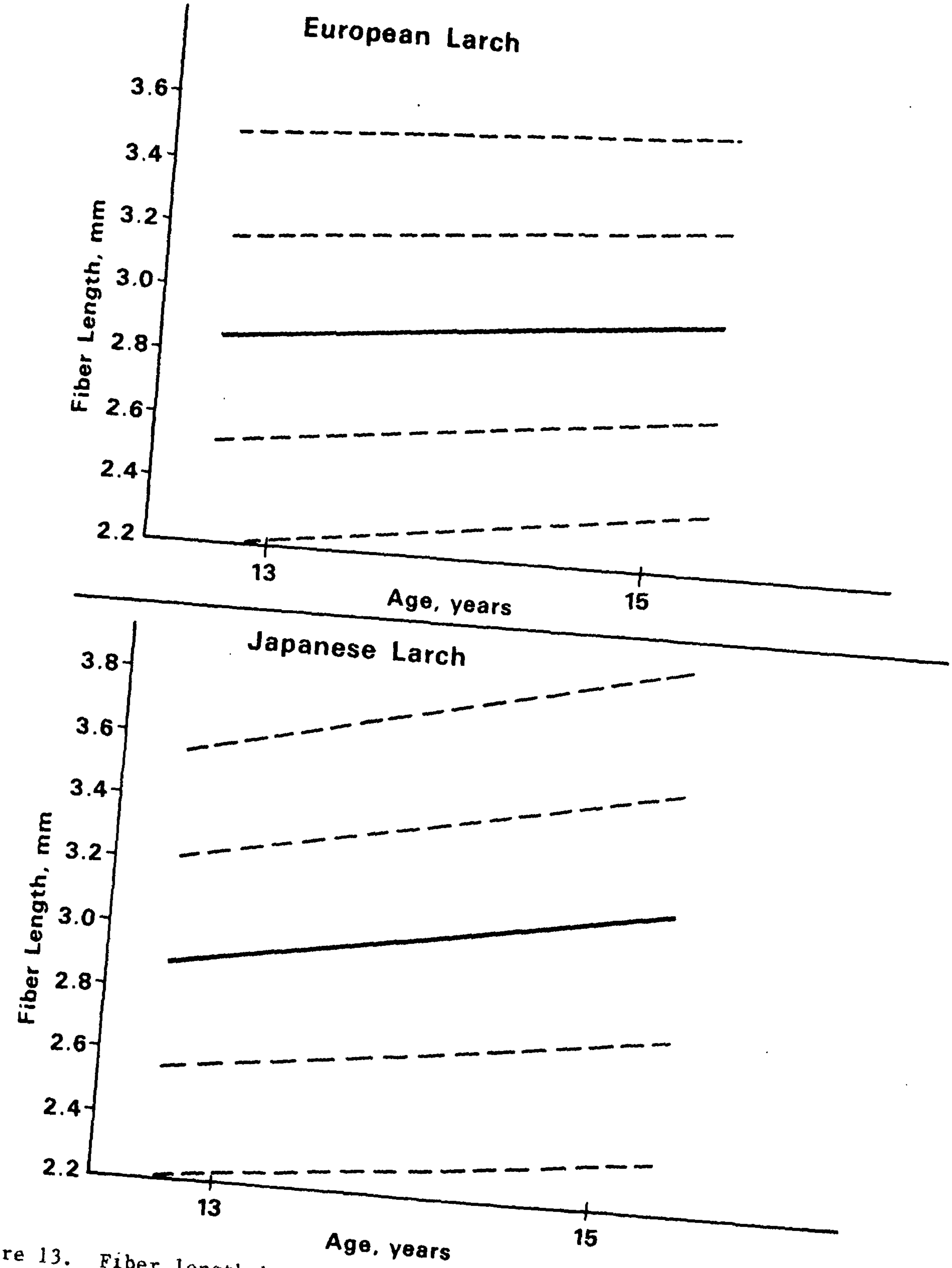

Figure 13. Fiber length base-line values for evaluating European and Japanese larch parent trees. Comparison made on breast height increment core samples. The solid line is the mean value and the dashed lines are one and two standard deviations ($s\overline{x}$) above and below the means.

OPERATIONAL PLANTINGS OF EUROPEAN LARCH - AN ECONOMIC ANALYSIS

SUMMARY

The economic returns from growing European larch at several rotation ages, growth rates, stumpage values, establishment costs, and management costs were investigated. Our best estimates suggest returns on investment are expected to vary from 3.6 to 8.6%, depending on the growth rate (site quality) and the stumpage values employed. For pulpwood production, the best rotation ages appear to be 22 to 25 years. It also appears that economic returns were more sensitive to changes in establishment costs than changes in annual management fees.

Economic returns for growing larch were compared with the estimated returns for growing pine and spruce. One assumption made was that for rotations of less than 30 years, European larch will outgrow red pine, jack pine, and white spruce on Vilas fine sand soils. Using current Wisconsin stumpage values, returns on investment were 1.2 to 1.6% greater for larch when compared to the pines and 2.4 to 3.1% greater for larch than white spruce.

INTRODUCTION

More frequently than ever forest managers are requesting that an economic analysis be performed prior to embarking on a major planting program with a new tree species. There are several ways the economics of growing European larch could be evaluated. The most widely used method, and the one used in this comparison, is to look at the "present worth of future returns" (PWFR) for a series of forest management assumptions. The technique is known as Faustman criterion of maximizing soil rent (or land expectation values) (2).

The approach used was to determine the silviculture and management costs associated with the management scheme selected, carry those costs forward at a predetermined interest rate to the end of the rotation, subtract these "capitalized" costs from harvest returns, and discount the net returns (or loss) back to time zero. This procedure gives the present worth of future returns (PWFR) for a single rotation. By repeating this step for a series of rotations, returns from a long-term management scheme can be determined. For discussion purposes all PWFR values will be called land expectation values because they represent the amount that could be paid for an acre of land and still make the rate of return indicated by the discount rate(s) employed.

STUDY OBJECTIVES

The objectives of Part I of this study were to look at the influence of several forest management factors (rotation age, growth rate, establishment costs, stumpage prices, and management costs) on the potential rate of return on investment for European larch.

The objective of Part II of this study was to compare, using the best information presently available, the rate of return from growing European larch with the anticipated returns from growing red pine, jack pine, white spruce, and northern hardwoods. This comparison was made for a medium-quality northern hardwood site (Vilas fine sand) in northern Wisconsin.

FOREST MANAGEMENT ASSUMPTIONS - PART I

The assumptions for Part I of the study were that the organization involved was interested primarily in the production of pulpwood in northern Wisconsin. Also, the organization had a variety of sites and was interested in determining what rotation age to use and the impact of growth and stumpage prices, establishment costs, and management costs on rate of return on investment from planting European larch. Further it was assumed that the organization had just completed harvesting the sites (clear cutting) and the harvesting operation had only partially prepared the sites for planting. Additionally, it was assumed future harvesting would be via "full-tree chipping"* and the area would be committed to the production of fiber for the next 90-100 years. Establishment costs included the cost of both site preparation and planting. The current stumpage prices used were based on values from the Wisconsin Forest Products Price Review (3). For larch, based upon pilot pulping results, the stumpage values used were equal to that of jack pine. Management costs were assumed to include taxes plus management charges. To simplify the evaluation, the following additional assumptions were made: (1) returns were based upon stumpage prices rather than wood delivered to the mill, (2) all returns were returns before taxes, (3) inflation rate was not considered in the analysis, (4) land value was not considered in the analysis. The site was considered to be owned by the organization, and the evaluations were being run to determine how best to utilize the site. Table 5 summarizes the variables investigated in the Part I economic evaluations.

FOREST MANAGEMENT ASSUMPTIONS - PART II

The assumptions for Part II, the comparison of the differences in economic returns from planting several alternative tree species, are very similar to those for Part I. The organization involved is interested primarily

*Use of the entire aerial portion of the tree excluding needles and leaves. This assumption allows the use of total volume growth data.

in the production of fiber. The sites in this case are all medium quality hardwood sites (Vilas fine sand or the equivalent). After harvesting the northern hardwoods on the area, the managing organization is faced with the decision regarding the future use of the site. The options considered are (1) growing European larch, (2) growing red pine, (3) growing jack pine, (4) growing white spruce, or (5) allowing northern hardwood regeneration to take over the area and managing the site for hardwood pulpwood. All returns are before taxes, inflation rate and land values are not considered in the analyses, and total volume production (as contrasted to merchantable volume) are used in estimating returns. Table 6 summarizes the economic variables investigated for red pine, jack pine, white spruce, and northern hardwoods. The reader should keep in mind the growth rates are not the maximum growth rates for each species but the estimated growth rates for Vilas fine sand soils.

Table 5. Economic variables investigated - European larch.

Variables	Values Investigated
Interest rates, %	4, 6, 8, 10
Rotation ages, years	18, 22, 25
Stumpage prices,* $/ft^3	0.12, 0.16, 0.20
Establishment costs,* $/acre	150, 200, 250, 300
Growth rate, ft^3/acre/year	120, 140, 160, 180, 200, 220, 240
Management costs,* $/acre	2.00, 2.50, 3.00, 3.50

* - Stumpage prices, establishment costs, and management costs are current values and were adjusted by increasing them at a rate of 1.5% per year, compounded.

Table 6. Growth and economic parameters for Vilas fine sand site.

Species	Site Index	Rotation Age, yr	Growth Rate[a] Medium	Growth Rate[a] High	Value,[b] $/cu ft	Reference[c]
Larch	90	30	120	140	0.18	IPC (4)
Red pine	70	30	96	112	0.17	Benzie
		45	89	101	0.17	(5)
N. hardwood	Medium	45	75	100	0.05	IPC (6)
W. spruce	64	45	88	100	0.10	Nienstaedt (7)
Jack pine	60	30	82	96	0.18	Benzie
		45	76	89	0.18	(8)

[a]Total volume production, most appropriate value (medium) and highest potential value for Vilas fine sand soils. See reference for sources of data.
[b]Wood value based on Peterson (3) Wisconsin Forest Products Price Review, Boltwood Edition, April, 1984.
[c]Reference for volume growth data.

ECONOMICS OF GROWING EUROPEAN LARCH - PART I

Preliminary Evaluations

The first series of computer runs compared rotation ages. In this series of trials, establishment and management costs were held constant at $200/acre and $3.00/acre/year, respectively (current costs were increased at 1.5%/year, compounded). Determined was the influence of growth rate and stumpage prices on land expectation values* and internal rate of return. Good reliable growth data for European larch is difficult to obtain. Based upon scattered growth information and site index data it was assumed that the MAI for good quality, fully stocked European larch plantations would vary as shown in Table 7.

*This is the same as soil rent or present worth of future returns.

Table 7. Estimated European larch growth rate, MAI[a].

Rotation Age, years	Site Quality Medium	Good	Excellent
18	120	160	200
22	140	180	220
25	160	200	240

[a]Cubic feet/acre/year total volume production.

The growth rate values in Table 7 were used to evaluate the effect of growth rate on economic returns. Table 8 summarizes the results of the first series of comparisons.

Calculations for the management plan that calls for growing European larch on 18-year rotations (Top, Table 8) indicate the return on investment will vary from 1.6% when stumpage values are $0.12/ft^3 and the growth rate is 120 ft^3/acre/year to 8.5% when the growth rate is 200 ft^3/acre/year and current stumpage prices are $0.20/ft^3 (ca. $18.00/cord). The land expectation values given are the values that could be paid for the land and still make either 4, 6, 8, or 10% return on the investment.

Also given in Table 8 are the estimated land expectation values and return on investment when 22 and 25 year rotations were considered. Similar variation in estimated land expectation values and rates of return on investment were obtained when these two rotations were considered.

Rotation Age

As a check on which of the three rotation ages under consideration would be economically the best, growth rate was held constant at 160 [illegible] Land expectation values ($) and return on investment (%) for European larch.

[illegible] Rate, [illegible] year	Stumpage, $/ft^3	Discount Rate - % 4	6	8	10	Rate-Return, %
		********** 18-Year Rotation **********				
[illegible]	0.12	-182	-207	-212	-214	1.6
	0.16	-39	-132	-168	-185	3.6
	0.20	104	-57	-123	-156	5.0
[illegible]	0.12	-39	-132	-168	-185	3.6
	0.16	151	-32	-108	-147	5.5
	0.20	342	67	-49	-108	7.0
[illegible]	0.12	104	-57	-123	-156	5.0
	0.16	342	67	-49	-108	7.0
	0.20	580	192	25	-60	8.5
		********** 22-Year Rotation **********				
[illegible]	0.12	-63	-151	-183	-197	3.3
	0.16	93	-72	-138	-170	4.9
	0.20	250	07	-93	-143	6.1
[illegible]	0.12	71	-83	-144	-174	4.7
	0.16	273	18	-87	-139	6.2
	0.20	476	119	-29	-103	7.5
220	0.12	205	-16	-106	-150	5.8
	0.16	453	108	-36	-107	7.3
	0.20	700	232	34	-64	8.6
		********** 25-Year Rotation **********				
160	0.12	22	-115	-166	-189	4.2
	0.16	200	-31	-120	-162	5.6
	0.20	379	53	-75	-136	6.6
200	0.12	156	-52	-132	-169	5.3
	0.16	379	53	-75	-136	6.6
	0.20	602	158	-18	-102	7.7
240	0.12	290	11	-97	-149	6.1
	0.16	557	137	-29	-109	7.5
	0.20	825	264	40	-69	8.6

Calculations based upon management cost of $3.00 and establishment costs of $200/A, both increasing at 1.5%/year compounded.

ft^3/acre/year and the rotation age and stumpage prices were varied as indicated in Table 9. When stumpage prices were \$0.12/ft^3, rotation age 25 appeared to be best. At \$0.16/ft^3 there was little in the way of difference in economic returns due to rotation age. At a stumpage price of \$0.20/ft^3 the 18-year rotation had a modest advantage in rate of return on investment. When one further considers that harvesting costs generally decrease as tree size increases and as volume per acre increases, the overall economics of the 22- and 25-year rotation are perhaps the best. It should also be pointed out the wood quality of 25-year-old trees will be modestly better than 18-year-old trees. Also, we generally believe for a specific site, the MAI will not be the same, as used in this comparison, but will be higher for the 22- and 25-year rotations.

Table 9. Land expectation values and rate of return vs. rotation age[a].

Rotation Age, yr	Stumpage, $/$ft^3$	Discount Rate - % 4	6	8	10	Rate-Return, %
18	0.12	-39	-132	-168	-185	3.6
	0.16	151	-32	-108	-147	5.5
	0.20	342	67	-49	-108	7.0
22	0.12	4	-117	-164	-186	4.0
	0.16	183	-27	-113	-154	5.6
	0.20	363	63	-61	-123	6.8
25	0.12	22	-115	-166	-189	4.2
	0.16	200	-31	-120	-162	5.6
	0.20	379	53	-75	-136	6.6

[a]Growth rate for each case is 160 ft^3/acre/year, establishment costs are \$200/acre, and management costs \$3.00/acre/year. (Costs were increased at 1.5%/year, compounded.)

Establishment Costs

The previous comparisons were made using establishment costs of \$200/acre. To determine the influence of establishment costs on rate of return, all factors were held constant (growth rate at 180 ft^3/acre/year, stumpage at \$0.16/ft^3, and management fee at \$3.00/acre/year) and establishment costs were varied from \$150 to \$300/acre*. The results of these calculations (Table 10) illustrate that land expectation values and rate of return on investment are very sensitive to establishment costs. As establishment cost increased from \$150/acre to \$300/acre, returns on investment dropped from 7.5 to 4.4%. The reason, of course, is because these up-front costs must be carried (capitalized) to the end of the rotation using the discount rates shown. The land expectation values given in Table 10 are the amount that could be paid for the land and make either 4, 6, or 8% return on investment. In other words \$273/acre could be paid if establishment costs were \$200/acre, and still make 4% rate of return on investment. As can be seen from this illustration, even though good site preparation is essential to early growth, it is important to keep costs down in order to make a reasonable rate of return.

Table 10. Land expectation values and rate of return _vs._ establishment cost.[a]

Establishment Costs, \$/acre	Discount Rates, % 4	6	8	Rate of Return, %
150	380	98	-20	7.5
200	273	18	-78	6.2
250	167	-62	-154	5.2
300	60	-141	-221	4.4

[a]Land expectation values (\$) when the growth rates is 180 ft^3/acre/year, the management fee is \$3.00 and the wood stumpage price is \$0.16/ft^3.

*Current cost, increasing at 1.5% per year, compounded.

Management Fees

Annual management fees for the previous comparisons were fixed at \$3.00/acre (current price) and were increased at a rate of 1.5%/year, compounded. To evaluate the sensitivity of economic returns to differences in management fees, they were varied from \$2.00 to \$3.50/acre/year. All other factors (growth rate at 180 ft^3/acre/year, stumpage value at \$0.16/ft^3, rotation age at 22 years, and establishment costs at \$200/acre), as in the case of establishment costs comparisons, were held constant. Table 11 illustrates the changes in land expectation values and rate of return as the result of varying management fee charges.

Table 11. Land expectation values and rate of return *vs.* management fee.[a]

Management Fee[b], \$/acre/year	Discount Rates, % 4	6	8	Rate of Return, %
2.00	310	41	-70	6.6
2.50	292	30	-79	6.4
3.00	273	18	-87	6.2
3.50	255	7	-95	6.1

[a]Land expectation values (\$) and return on investment when growth rate is 180 ft^3/acre/year, stumpage price is \$0.16/ft^3 and establishment costs were \$200/acre.
[b]Management fees were increased at 1.5%/year, compounded.

Changes in management fee costs, as Table 11 illustrates, have relatively little influence on economic returns. Increasing the management fees from \$2.00 to \$3.50/acre/year resulted in a decrease of just 0.5% in return on investment (6.6% *vs.* 6.1%).

LAND EXPECTATION VALUES AND RATE OF RETURN FOR CONIFER SPECIES GROWING ON VILAS FINE SAND - PART II

The objective of Part Two of this investigation was to compare the economics of growing European larch with several alternative species. Table 6 summarizes the parameters considered and the species utilized in this comparison. Table 12 provides the land expectation values and the rate of return information generated. European larch, when compared in field planting to the other species, quite consistently exhibited better growth than either jack pine or red pine and much better growth than spruce or northern hardwood. Stumpage prices used for larch were the same as for jack pine* and slightly higher than red pine (Table 6). When these higher growth rates and appropriate (not excessive) stumpage values were used, European larch had the best land expectation values and the highest rate of return on investment of the species compared. Red pine had a less favorable economic return because of lower growth rate and lower stumpage prices. White spruce and northern hardwoods both have low rates of return. Northern hardwoods low economic returns, despite low establishment costs, are because of the low growth rates, the required long rotations, and low value of wood produced. The low economic returns of white spruce results because of modest growth rate, medium stumpage values, and long rotations. The lower stumpage values of red pine apparently reflect industry's recognition of the low pulp yields, low wood specific gravity, and lower strength of pulp from plantation grown red pine. The lower stumpage values for white spruce reflect increased harvesting costs.

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*We actually feel that European larch should have higher stumpage values than jack pine because the volumes per acre will be higher, the trees will be better pruned (lower harvesting cost) and pulp yields are expected to be 2-4% higher.

Table 12. Species comparison, land expectation values and rate of return[a].

Species	Rotation Age, yr	Growth Rate, ft^3/acre/year	Discount Rate - % 4	6	8	Rate-Return, %
Larch	30	120	95	-91	-159	4.8
		140	186	-49	-138	5.4
Red pine	30	96	-39	-151	-190	3.6
		112	31	-119	-174	4.3
	45	89	-68	-183	-215	3.5
		101	-25	-167	-208	3.8
Jack pine	30	82	-80	-170	-200	3.2
		96	-15	-140	-184	3.9
	45	76	-95	-193	-219	3.2
		89	-50	-176	-212	3.6
White spruce	45	88	-197	-231	-234	2.0
		100	-172	-221	-230	2.3
N. hardwoods	45	75	-67	-69	-65	1.7
		100	-41	-60	-61	2.8

[a]Land expectation values ($) at discount rates of 4, 6, and 8%. The management fee used was $3/acre/year, increasing at 1.5%/year, compounded. Establishment costs were $200/acre for larch, red pine, jack pine, and white spruce and $25/acre for northern hardwoods, all increasing at 1.5%/year, compounded.

When management of red pine and European larch was simulated under a procedure where the plantations were thinned for pulpwood at 22 years and then harvested for box bolts and pulpwood at age 30, the rate of return on investment increased modestly (increased 0.6 to 0.7%). Similar management procedures that involved even longer rotations (40-50 years) and higher value products were not investigated but could be expected to result in additional modest increases in return on investment.

PLANS FOR 1985-86

The emphasis of the coming year's work will be on the propagation and establishment of clonal material for European larch seed orchards. Three half orchards are scheduled for planting the spring of 1985 and an additional two to three half orchards for 1986. An application for the importation of restricted plant materials has been made and if approved will allow us to bring in additional parent material this spring without having to first introduce it through Canada. The remaining seven U.S. selections will be grafted if possible.

Herbicides for larch establishment will be screened. A small site preparation trial will be put in on Consolidated Paper's lands this coming spring to evaluate several chemicals. Other establishment methods being used by cooperators will be observed and discussed with the intention of arriving at recommendations for larch establishment.

Cooperation with USFS pathologists in a larch needle cast screening trial is planned for this coming spring. We have provided six documented seed sources encompassing much of the range of _L. decidua_ along with two sources of hybrid larch and one source of Japanese larch. Several of the sources are from origins being recommended for use in the larch project.

Discussions during last year's annual meeting about the possibility of including tamarack seemed to indicate that we should begin selecting. If tamarack is considered a useful addition to the project, selection will begin this coming year.

Stock for a provenance trial and an additional replicated field trial will be produced. The bareroot _vs._ container trial planned for this spring had to be delayed, but the production of stock for this type of trial is again planned for this year.

Known origin larch seed will again be sought. Long term cooperative arrangements are being developed and the availability of modest amounts of larch seed is becoming more assured. However, the high value placed on this seed (up to $275/lb for hybrid seed and $250 for European larch) continues to underscore the necessity of getting our own seed orchards established and into production. If time and circumstances permit, a visit to the State of Pennsylvania's Japanese larch seed orchards is planned.

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APPENDIX

Table 13. European larch parent tree selections - seed origin.

Material	Origin	Distribution Group[a]	Cooperator and Location
LD-10-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-11-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-12-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-1-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-2-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-3-80	Wroclaw, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-4-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-5-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-6-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-7-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-8-80	SSUI[b]	Alpen	Wisconsin DNR, LaCrosse, WI
LD-9-80	SSUI[b]	Alpen	Wisconsin DNR, LaCrosse, WI
LD-10-80	SSUI[b]	Alpen	Wisconsin DNR, LaCrosse, WI
LD-11-80	Tirol, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-12-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-13-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-14-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-15-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-16-80	Zagnansk, Poland	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-17-80	Zagnansk, Poland	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-18-80	Unknown	Unknown	U.S. Forest Service, Rhinelander, WI
LD-19-80	Nodebo, Denmark	Sudeten[b]	U.S. Forest Service, Rhinelander, WI
LD-20-80	Kronborg, Denmark	SSUI[b]	U.S. Forest Service, Rhinelander, WI
LD-21-80	Palsgaard, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-22-80	Nodebo, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-23-80	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-24-80	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-25-80	SSUI[b]	SSUI	Hammermill Paper Co., Cattaraugus, NY
LD-26-80	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-27-80	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-28-80	SSUI[b]	SSUI	Hammermill Paper Co., Mina Hollow, PA
LD-29-80	SSUI[b]	SSUI	Hammermill Paper Co., Mina Hollow, PA
LD-30-80	SSUI[b]	SSUI	Hammermill Paper Co., Mina Hollow, PA
LD-31-80	SSUI[b]	SSUI	Hammermill Paper Co., Mina Hollow, PA
LD-1-81	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-2-81	Zagnansk, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-3-81	Aroretet, Denmark	Unknown	U.S. Forest Service, Rhinelander, WI
LD-4-81	Palsgaard, Denmark	Polen	U.S. Forest Service, Rhinelander, WI
LD-5-81	Nodebo, Denmark	Polen	U.S. Forest Service, Rhinelander, WI
LD-6-81	Palsgaard, Denmark	Polen	U.S. Forest Service, Rhinelander, WI
LD-7-81	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-8-81	SSUI[b]	SSUI	Hammermill Paper Co., Potter, PA
LD-9-81	SSUI[b]	SSUI	Hammermill Paper Co., Potter, PA
LD-10-81	SSUI[b]	SSUI	Hammermill Paper Co., Potter, PA
LD-11-81	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-12-81	SSUI[b]	SSUI	Scott Paper Co., Waterville, ME
LD-13-81	SSUI[b]	SSUI	Scott Paper Co., Waterville, ME

See end of table for footnotes.

APPENDIX

Table 13 (Continued). European larch parent tree selections - seed origin.

Material	Origin	Distribution Group[a]	Cooperator and Location
LD-1-82	Zagnansk, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-2-82	Lot 55, Sweden	SSUI	U.S. Forest Service, Rhinelander, WI
LD-3-82	Zagnansk, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-4-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-5-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-6-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-7-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-8-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-9-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-10-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-11-82	Dobris, Czechoslovakia	SSUI	U.S. Forest Service, Rhinelander, WI
LD-12-82	Dobris, Czechoslovakia	SSUI	U.S. Forest Service, Rhinelander, WI
LD-13-82	Zabreh-Dubicko, Czechoslovakia	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-14-82	Ruda nad Morovou, Czechoslovakia	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-15-82	Skarzysko, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-16-82	Skarzysko, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-17-82	Schlitz, Germany	SSUI	U.S. Forest Service, Rhinelander, WI
LD-18-82	Skarzysko, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-19-82	Schlitz, Germany	SSUI	U.S. Forest Service, Rhinelander, WI
LD-20-82	Unknown	Unknown	Diamond International, Milo, ME
LD-22-82	Pinczow, Poland	Polen	State of New Hampshire, Hillsboro, NH
LD-23-82	Salzburg, Austria	Alpen	State of New Hampshire, Hillsboro, NH
LD-24-82	Brenensky, Czechoslovakia	Sudeten	State of New Hampshire, Hillsboro, NH
LD-26-82	Salzburg, (Bluhnbach) Austria	Alpen	State of New Hampshire, Hillsboro, NH
LD-27-82	SSUI	SSUI	University of Maine, Orono, ME
LD-28-82	SSUI	SSUI	University of Maine, Orono, ME
LD-1-83	SSUI	SSUI	Champion International, Natham, MI
LD-2-83	Val di Fiemme, Italy	Alpen	State of New Hampshire, Hillsboro, NH
LD-3-83	County Moray, Scotland	SSUI	State of New Hampshire, Hillsboro, NH
LD-1-84	SSUI	SSUI	State of Maine, Atkinson, ME

[a]Four separate distributional groups are recognized within the geographical range of European larch: Alpen, Sudeten, Tatra, and Polen plus several smaller outliers in Rumania. Major genetic differences are found between and within these groupings.
[b]Seed source under investigation.

APPENDIX

Table 14. Japanese larch parent tree selections - seed origin.

Material	Origin	Cooperator and Location
LL-4-59,S-1	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-4-59,S-2	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-12-59,S-1	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI
LL-1-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-2-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-3-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-4-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-5-80	Tochigi Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-6-80	Tochigi Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-7-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-8-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-9-80	Latitude 35° 54', longitude 137° 34'	Packaging Corporation of America, Bear Lake, MI
LL-10-80	Latitude 35° 54', longitude 137° 34'	Packaging Corporation of America, Bear Lake, MI
LL-11-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-12-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-13-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-14-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-15-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-16-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-17-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-18-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-19-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-20-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-21-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-22-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-23-80	SSUI[a]	Glatfelter Pulp Wood Co., Hershey, PA
LL-24-80	SSUI[a]	Glatfelter Pulp Wood Co., Hershey, PA
LL-1-81	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-3-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-4-81	Gumma Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-6-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-7-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-8-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-9-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-10-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-11-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-12-81	SSUI[a]	Scott Paper Co., Oxford City, ME
LL-2-59,S-1	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-5-82	Hokkaido, Japan	IPC Larch Trial I, Eagle River, WI
LL-6-82	Hokkaido, Japan	IPC Larch Trial I, Eagle River, WI
LL-7-82	SSUI	International Paper Co., Readfield, ME
LL-8-82	SSUI	Glatfelter Pulp Wood Co., Fort Littleton, PA
LL-9-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Huston, PA
LL-10-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Maddensville, PA
LL-11-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Huston, PA
LL-12-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Huston, PA
LL-13-82	SSUI	Diamond International, Milo, ME
LL-1-83	Yatsuga Mts., Japan	University of Wisconsin, Rhinelander, WI
LL-2-83	Yatsuga Mts., Japan	University of Wisconsin, Rhinelander, WI
LL-3-83	Yatsuga Mts., Japan	University of Wisconsin, Rhinelander, WI
LL-4-83	SSUI	University of Wisconsin, Rhinelander, WI
LL-5-83	SSUI	University of Wisconsin, Rhinelander, WI
LL-6-83	Unknown	State of New Hampshire, Hillsboro, NH
LL-7-83	Central Japan	State of New Hampshire, Hillsboro, NH

[a]See source under investigation.

APPENDIX

Table 15. *Larix gmelini* and *Larix dahurica* parent tree selections seed origin.

Material	Origin	Cooperator and Location
LDa-14-59, S-1	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI
LDa-14-59, S-2	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI
LDa-1-83	Unknown	State of New Hampshire, Hillsboro, NH
LG-13-59, S-1	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI

GLOSSARY

FOREST GENETICS TERMS

Clone - a group of plants derived from a single individual (ortet) by asexual reproduction. All members (ramets) of a clone have the same genotype and, consequently, tend to be uniform.

Compression wood - Wood of dense structure formed at the bases of some trees and on the underside of branches in conifers.

Cyclophysis - Abnormal growth that occurs in a graft when scion material is collected from too low an area in the crown.

Cytochromes - Cytochrome a, b, and c are heme-containing proteins widely occurring in cells and acting as oxygen carriers during cellular respiration.

F_1 generation - The first generation of a mating. If each parent is true breeding (homozygous), the F_1 individuals always resemble each other.

F_2 generation - The second generation successive to the parents and produced by crossing or selfing the F_1 individuals. The individuals within an F_2 generation characteristically vary greatly when their F_1 parent or parents are heterozygous.

F_3 generation - The third generation produced by intercrossing or selfing F_2 individuals. Individuals within an F_3 generation characteristically vary greatly.

Full-sib - Progeny, irrespective of sex, having the same male and female parent but from separate fertilizations.

Half-sib - Progeny, irrespective of sex, having only one parent in common.

Hedging - Reducing a plant to a more juvenile stage by repeatedly cutting it back and forcing a large number of shoots.

Heterozygosity - Presence in the same plant of both the dominant and recessive gene. A heterozygous individual characteristically does not breed true.

Homozygosity - Presence in a plant of either the dominant or recessive gene but not both. A homozygous individual breeds true when mated with the same genotype for the character(s) in question.

Inbreeding depression - Loss of vigor and/or fertility through intercrossing or selfing related organisms.

Isozyme (isoenzyme) - Multiple forms of a single enzyme. Isozymes often have different isoelectric points and therefore can be separated by electrophoresis.

Plagiotropism - A growth response to gravity, so that the axis of the plant member makes an angle other than 90° with the line of the gravitational field. See cyclophysis and topophysis.

Propagule - A plant part, such as a bud, tuber, root, or shoot, used to reproduce an individual asexually.

Provenance - The original geographic source of seed or propagules.

Topophysis - Abnormal growth that occurs in a graft when scion material is collected from the wrong branch positions.

PULPING AND SOLID WOOD PRODUCT TERMS

Basic density - Specific gravity of wood based on green volume. The term basic is applied since both green volume and ovendry weight are as nearly constant and reproducible measurements as can be obtained with wood.

Breaking length - The length of a strip, usually expressed in meters, which would break of its own weight when suspended vertically.

Bursting strength - The hydrostatic pressure in pounds per square inch required to produce rupture of the material when pressure is applied at a controlled increasing rate through a rubber diaphragm to a circular area.

CEDED bleaching - Sequence of chlorination, alkali extraction, chlorine dioxide, extraction, and chlorine dioxide.

Coarseness - The weight per unit length of a single fiber. Usually expressed as mg/100 m and considered to be useful in predicting fiber behavior in papermaking.

Density - Mass per unit volume; i.e., grams per cubic centimeter; lbs per cubic foot. See specific gravity.

Freeness - A measure of the rate at which water drains from a stock suspension through a wire mesh screen or a perforated plate. It is also known as "slowness" or "wetness" according to the type of instrument used in its measurement and the method of reporting results.

Furnish - The mixture of various materials that are blended in the stock suspension from which paper or board is made. The chief constituents are the fibrous material (pulp), sizing materials, wet-strength or other additives, fillers, and dyes.

Handsheet - A sheet made from a suspension of fibers in water, with or without the addition of sizing, loading, or coloring agents. Each sheet is formed separately by draining a pulp suspension on a stationary mold called a sheet mold. It is generally used for testing the physical properties of the pulp and/or the combinations of pulp with other material, in which case the sheet must be formed in accordance with standard procedures.

Kappa no. - Related to the amount of lignin left in the pulp. Decreasing numbers mean less lignin left in the pulp.

Modulus of elasticity - The proportionality constant (K) relating stress and deformation; it indicates the ability of the material to recover its original shape and size after the stress is removed.

Modulus of rupture - The maximum bending load to failure in pounds per square inch.

Specific gravity - The ratio of weight of a substance to the weight of an equal volume of water. Usually expressed as moisture free weight over green volume.

Spiral grain - Grain in which the fibers are aligned in a helical orientation around the axis of the stem.

Tearing resistance - The force required to tear a specimen under standardized conditions. There are three terms in common usage: (1) internal (or continuing) tearing resistance, wherein the edge of the specimen is cut prior to the actual tear. The value is commonly expressed in grams of force required to tear a single sheet. (2) "Edge tearing resistance." (3) Torsion tearing resistance of paper or paperboard is the energy expended in propagating a tear when the tearing force is applied in such a manner as to create a twist or torque.

Tensile strength - The force, parallel with the plane of the paper, required to produce failure in a specimen of specified width and length under specified conditions of loading. This definition must be distinguished from that which is commonly used in engineering practice and which expresses the tensile strength in force per unit area. In the paper industry, it is expressed as load per unit width or as "breaking length."

Zero-span tensile strength - The tensile strength of a sheet of fibrous material, measured with special jaws, at an apparent initial span of zero. It is an indication of the strength of the material comprising the fiber.